Debiasing the Hot Hand

Honors Research Thesis

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by

Sam DeSalvatore

The Ohio State University

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Project Advisor: Professor Michael DeKay, Department of Psychology

Abstract

Gilovich et al. (1985) found the presence of the hot hand belief in basketball. Since then, it has been found in many other sporting domains. However, to date, there have been no published successful debiasing techniques. The current study will attempt to replicate Gilovich et al.'s results as well as provide a simple yet successful debiasing technique involving base rates (season shooting percentages). We found evidence against the presence of the hot hand but found the relevance of base rate information.

Introduction

In the world of sports, people see streaks everywhere they look. Whether it is a field goal kicker making twenty-one of his past twenty-two attempts, or a baseball player on a fifteen-game hit streak, we attribute these streaks to the players and assume that they are hot. Even though outside observers view these athletes as being on a streak, it has been shown that statistically speaking, sequences that appear to be streaks are really part of what can be expected from a random process, therefore, streaks in sports really just result from random processes (Adams, 1992; Vergin, 2000).

The hot hand is a “belief in positive autocorrelation of a non-autocorrelated random sequence of outcomes” (Sundali & Croson, 2006, p.1). This means that observers tend to think that a when a player in a basketball game makes a few shots in a row, he is more likely to make his next shot, even though all of the shots are independent from one another. This misunderstanding of the statistical properties of sequences has many implications in the sporting world and in everyday thinking.

The gambler’s fallacy is the counterpart to the hot hand belief. It is “a belief in negative autocorrelation of a non-autocorrelated sequence of outcomes like coin flips” (Sundali & Croson, 2006, p.1). This statement means that in situations such as coin flips, people expect streaks of outcomes to end. For example, if someone flipping a coin sees four heads in a row come up, that person would expect for the next flip to come up as tails. He or she would hold this expectation because the results of the previous four flips were heads and that person would not expect a fifth head in a row to appear.

These two biases stem from the same misperception. When making a judgment about a sequence of independent events, one must keep in mind what independence means. If a sequence of coin flips or basketball shots is indeed independent, then the outcome of the previous event has no bearing on what the outcome of the subsequent events will be. For example, if a coin is flipped and has come up heads three times in a row, tails is no more likely to come up on the next trial than heads. Regardless of the previous outcomes, each side has a 50% chance of appearing in any given trial. The same can be said for basketball. Just because a player has made his four previous free throws does not mean that he is more likely to make his next because those free throws are statistically independent events.

According to Tversky and Kahneman (1974), the hot hand belief and the gambler's fallacy arise from misuse of the representativeness heuristic. The representativeness heuristic is when someone expects a sample, such as the sequence of coin flips described above, to match or be representative of their mental prototype they have formed about the larger group which that sample represents (Tversky & Kahneman, 1974). Using the same coin flip example, this means that people do not think the next flip will be heads because their mental picture of what the sequence of outcomes should look like does not match the result of getting five heads in a row. Tversky and Kahneman (1971) found that people expect the characteristics of a chance process, such as a coin flip or roll of the dice to occur within the entire sequence but to also occur locally in each part of the sequence. This means that if the probability of rolling a die and getting a three is 1/6, then people expect for three to be about 1/6th of the outcomes recorded in an entire sequence and also for it to appear once in any randomly selected string of six outcomes. They called this phenomenon the “belief in the law of small numbers.” This misconception of chance resulting from the representativeness heuristic causes people to believe that, for example, a sequence of foul shots that contains four makes in a row is not a random sequence. This effect is shown even when there are just one or two makes or misses in a row at the end of a sequence of free throws (Gilovich, Vallone & Tversky, 1985). People have this misconception because the number of makes in a row is not representative of what they would expect in a sample of a random sequence (Wagenaar, 1972).

While both the gambler’s fallacy and hot hand belief explain people’s beliefs about random sequences, they are very distinct biases that occur under unique circumstances. First, the gambler’s fallacy (predicting that a run will end) is generally used when describing judgments made about chance events (coin flips, dice, etc.). Second, the hot hand belief (predicting that a run will continue) is generally used when describing human skill events (basketball shots, football field goals, etc.) and events whose outcomes are seemingly controlled by humans (Caruso, Waytz & Epley, 2010). This rejection of the idea of randomness for a sequence of outcomes in favor of the idea that a streak is present is in essence the hot hand.

The belief in the hot hand was first tested by Gilovich, Vallone and Tversky (1985). They tested for the presence of the hot hand belief in basketball. In their study, the researchers analyzed field goal and free throw data from the National Basketball Association and found no evidence of streak shooting in the players sampled. They also surveyed basketball fans and asked for their percentage estimate of the chance that a shooter has of making his next shot following a make or a miss. As shown by their percentage estimates, participants thought it was more likely for a shooter to make his next shot if he had just made the previous one. This result showed people's belief in streak shooting. Lastly, in a controlled shooting experiment, Cornell basketball players bet on whether or not they would make a fifteen-foot jump shot. The betting was the measure of the hot hand. Participants bet high if they were confident about their prediction and low if less confident. They repeated this for 100 shots and found that there was no evidence for streak shooting. Furthermore, it was found that both players and observers bet a higher amount that they would make their next shot after a make than after a miss. These results show a couple of different things. First, they found that there was no evidence for streak shooting but that there was a constant belief in the hot hand by both those playing and watching the game. Gilovich et al. hypothesized that this belief could be due to a memory bias, stating, "if long sequences of hits (or misses) are more memorable than alternating sequences, the observer is likely to overestimate the correlation between successive shots" (Gilovich et al., 1985, p.310).

Another explanation given for the belief in the hot hand is people's misconception of the nature of chance. An alternation is when, in a sequence of binary outcomes, the outcome switches from one possible outcome to the other. The alternation rate of a sequence is the proportion of times that there is an alternation of outcomes within that sequence. Gilovich found that the percentage of participants who thought a sequence was a result of streak shooting decreased as the number of alternations in the sequence increased. For example, consider the sequence XXOXOOXOOXX. This sequence is made up of eleven trials. Out of a possible ten alternations, there are 6, producing an alternation rate of 6/10 or .6. This is found by starting at the beginning of the sequence and simply counting the number of times the outcomes in the sequence alternate. This number is then divided by N-1, where N=the number of outcomes in the sequence.

Gilovich et al.'s finding is supported by Ayton and Fisher (2004), who found that people attribute sequences with a higher alternation rate to chance events and sequences with lower alternation rates to events produced by skill. They obtained their result by testing to see whether participants attribute sequences to chance events or to human skill events. Participants viewed a streak and were asked to say if they thought the streak was produced by a chance event (coin toss, roulette wheel, dice throw), or a human skill event (basketball shooting, soccer scoring, or tennis serving). They found that a series with a lower alternation rate, thus exhibiting positive recency (predicting the same outcome as the last), was judged more likely to be produced by human skill while a series with a higher alternation rate, thus exhibiting negative recency were judged more likely to be produced by chance (Ayton & Fisher, 2004).

While Gilovich et al. were able to show the belief in the hot hand, they did not ask participants to estimate the likelihood that a player would make his next shot after viewing a sequence of shots all at once. The results of their survey in Study 1 show that people believe that a player is more likely to make the next shot after having made the previous few. They also showed that when people viewed a sequence of X's and O's and the alternation rate was low enough, they believed that the sequence resulted from streak shooting. The researchers did not ask participants to make a judgment about the next shot after viewing a sequence. We believe that it is important to test the belief in the hot hand this way because they would be experiencing the hot hand in action. If people say they believe in the hot hand but do not show it when the conditions that would foster this belief are presented, then there would be an inconsistency in their beliefs and actions. We predict that people will still fall victim to the hot hand belief even when viewing and making judgments about sequences in front of them.

To date, we know of no efforts that have successfully debiased the hot hand belief. This is important because the hot hand belief is the cause of many errors in judgment in both the gambling world and sports world. People's belief in the hot hand influences their thoughts and actions related to the outcomes of sporting events. The aims of the present study are to 1) replicate Gilovich's hot hand result using sequences and 2) find a way to debias or get people to not fall victim to the hot hand belief when judging streaks that should produce the hot hand belief. In this experiment we will test the hot hand by showing participants sequences of X's and O's, which should produce a hot hand result. We expect to be able to debias people from the hot hand belief by providing them with base rate information, which in this case is the player's season shooting percentage, along with the sequences. We hypothesize that the debiasing will have the greatest effect on participants who see the shooter's base rate after the sequence of shots rather than before the sequence, due to order effects of base rate information. This is where people who see a base rate immediately before making a judgment will use it more (Krosnick, Li, & Lehman, 1990). We also hypothesize that the debiasing technique will work better on those who are shown to have better numerical ability, since the base rate is presented in numeric (percentage) form and they will be able to understand it better.

Method

Participants

One hundred fifty-one adults living in the United States were recruited through Amazon's Mechanical Turk website and received payment for completing the study. The mean age was 35 years, while 47% were male and 53% female. 28% of participants held a four-year college degree, 12% a graduate degree, and 15% a high school diploma, while the rest had some high school, some college, or some graduate education. The median income category was $40,000-$59,999.

Materials and Procedure

Participants completed a computer survey in which they were asked to judge whether they believed that a streak of field goals in basketball was likely to continue. Each participant viewed eighteen different sequences of twelve shots where an X represented a make and an O represented a miss (e.g., XOOXXOXOOXXX). The patterns differed in two ways. First, a third of the sequences contained five X's, a third contained six X's, and a third contained seven X's. Second, the sequences ended with one, two, or three makes or misses in a row. All sequences had an alternation rate of either .45 or .55. The alternation rates were controlled so that they would not have an effect on participants' judgments.

There were two debiasing conditions and one control condition in the experiment. The control condition contained only the sequence of shots for participants to see before making their judgment of the chance that the player will make his next shot. In one debiasing condition, the *base rate before* condition, participants viewed the player's shooting percentage for the first half of the season (i.e., the base rate), then scrolled down the page to see both the base rate and the shooting sequence for that game before making their judgment. In the *base rate after* condition, participants viewed the shooting sequence and then scrolled down to see both the shooting sequence and the base rate before making their judgment. In both debiasing conditions, the base rates ranged from 41% to 58% in steps of 1% and were randomly paired with the sequences. The dependent variable was the estimated percentage that the player will make his next shot for each trial.

Participants were randomly assigned to one of the three conditions. After participants in each condition provided their estimates for the eighteen sequences, they were asked six questions regarding their beliefs about basketball. Questions about basketball beliefs and attitudes were the same as those used in Study 1 of Gilovich et al. (1985). For example, “Do you believe that a player has a better chance of making a shot after making their last two or three shots than after missing their last two or three shots?” Afterwards, participants completed an eight-item numeracy measure (Weller, Dieckmann, Tusler, Mertz, & Peters, in press). Last, participants provided demographic information including gender, age, income level, education level, and race.

Results

As shown in Figure 1, no evidence of the hot hand belief was found. In fact, evidence of the opposite belief, the gambler's fallacy, was observed. The fact that all three lines on the graph have a negative slope indicates the presence of the gambler's fallacy. This is true because the percentage estimates are higher for the sequences that end in three misses than for those which end in three makes. If we had observed participants acting according to the hot hand belief, the opposite would have been true and the lines would have had a positive slope.

We hypothesized that the presence of base rates, especially those seen after viewing a sequence would debias the hot hand belief. The hypothesis was confirmed, but not in the direction expected. For the participants who saw the base rates to be successfully debiased, their percentage estimates given should be more aligned with the base rates and less influenced by the end of the sequences than those given by participants in the control condition. We expected for the estimates given by participants in the base rate after condition to be the most aligned with the base rates. Last, contrary to our predictions, numerical ability had no effect on the belief in the hot hand or the use of base rates.

Further evidence against the presence of the hot hand belief was found when the data were analyzed using a repeated-measures regression model. As seen in Table 1, the coefficient for the term *sequence end* was $\beta=-1.5233$, $z=-4.9$, $p<.0001$. This means that as the number of makes at the end of each sequence increased by one, the percentage estimates given by the participants decreased on average by about 1.5 percentage points. If the hot hand were present, this term would be positive. So far in tests of people's estimates of likelihoods of making a basketball shot, there is evidence suggesting that the hot hand belief does not exist. People clearly provide lower estimates when they see more makes at the end of a sequence and higher estimates when they see more misses.

While no direct evidence of the hot hand was found, base rates did influence people's judgments. Another multilevel regression was run including base rates into the equation this time. As shown in the results in Table 2, people used base rates to help make their judgments when presented with them. The term *base rate* (β=.8364, z=8.98, p<.0001) means that for each percentage point increase in the base rate seen by a participant, his or her estimate increased by .83 percentage points.

This is also seen in the trend in Figure 1. The two lines representing the two base rate conditions have a smaller slope than the control condition. The regression model in Table 3 shows that the presence of base rates caused people to use the information at the end of the sequence less when making their judgments. The positive coefficient on the interaction term between *sequence end* and *base rate conditions* is means there is less weight placed on the sequences when base rates are present. This term is only marginally significant (β=1.3354, z=1.80, p=.07), but still indicates that people are using the base rates in the correct way to debias the gambler's fallacy. This shows that the base rates are influencing participants to make different judgments about the future success of the shooter than they otherwise would without that information present. It must also be noted that the slopes two base rate lines were not significantly different from each other and are nearly identical. The similarity of the two base rate conditions shows that there was no order effect for base rates found. Participants are treating the base rates to be equally valid and using them in the same way whether they saw them before or after viewing the sequences. These results show that even though we did not find evidence for the hot hand, participants still used base rates to debias the gambler's fallacy in the way that we had intended for them to.

After testing for the presence of the hot hand belief by having the participants view sequences of makes and misses and then asking for a judgment, they were then asked questions concerning their beliefs about basketball. These questions were used to assess whether participants would display beliefs consistent with the hot hand belief.

The questions were the exact questions used by Gilovich et al. (1985). Figure 2 shows the results compared with the results obtained by Gilovich et al. For each question, an answer of "yes" showed a belief consistent with the hot hand belief. As shown, a lower percentage of participants answered "yes" to each question in the present study than in Gilovich et al.'s original study.

The first two questions asked were: "Do you believe that a player has a better chance of making a shot after making their last two or three shots than after missing their last two or three shots?" and "Do you believe that a player has a better chance of making the second free throw after making the first free throw than after missing the first free throw?" The results as shown in Figures 2A and 2B show the percentages of people who said yes in the present study were 46% and 51% respectively. When tested against a null-hypothesis value of 50% yes, neither of the percentages for the first ($z=-0.90$, n.s.) nor the second ($z=0.24$, n.s.) questions differed significantly.

The last two questions asked were: "Do you think that after having made a series of shots in a row, basketball players tend to take more shots than they normally would?"

and “Do you believe that it is important for players to pass the ball to a teammate who has just made several (two, three or four) shots in a row?” The results shown in Figures 2C and 2D show the percentages of people who said yes were 71% and 60% respectively. When tested against a null-hypothesis value of 50% yes, both the percentages for the former ($z=5.13$, $p<.0001$) and the latter ($z=2.52$, $p<.01$) questions differed significantly.

The results from these four questions reveal a few different things. First, participants on average did not believe that a player was more likely to make a shot, whether a field goal or free throw, because he had made his previous shot or shots. Second, even though participants do not believe a player is more likely to make a shot after having made the previous few, they do believe that the same player tends to take more shots and should get the ball more. Last, percentages of people who answered “yes” were lower than Gilovich et al.’s study for every question and in some cases were not statistically different from chance. These findings affirm the findings from the beginning of the section that participants do not hold a belief in the hot hand.

Discussion

Even though evidence for the presence of the hot hand belief was largely absent, base rates were found to debias the gambler's fallacy. This surprising result of no evidence of the hot hand belief came after testing for the presence of the hot hand in a couple of ways. First, we tested by using sequences of shots that have characteristics conducive to producing a hot hand belief (Gilovich et al., 1985; Ayton & Fisher, 2004). Second, we tested by asking the same questions Gilovich et al. asked their participants regarding their beliefs about basketball.

While not finding any evidence for the hot hand belief was unexpected, there are five explanations as to why this might be. First, seeing a sequence of X's and O's could evoke a thought process consistent with the gambler's fallacy. Depicting the shots this way is not how people usually experience basketball data. They usually see the players shooting the ball or hear an announcer say, "He made nine of his last twelve down the stretch." This disconnect from the way that people are used to receiving information about basketball and the way that we presented it could have led them to not think about basketball and thus not exhibit the hot hand belief. This may have happened despite the cover story discussing a basketball player's shots. In this case it could be that seeing a string of X's and O's, which could have unintentionally produced a gambler's fallacy belief, overrode the cover story intended to produce a hot hand belief. This explanation seems unlikely due to previous research finding the hot hand when presenting information the same way the current study did (Tyszka, Zielonka, Dacey, & Sawicki, 2008).

Second, people may not believe that the sequence they are seeing is produced by a non-random process. It has been shown that people rate shots in basketball as less random than roulette spins and therefore should judge basketball streaks as likely to continue (Burns & Corpus, 2004). The sequences in this study may not have violated participants' assumptions of them being randomly produced; therefore they would not have judged a player's skill as the cause of their "hotness" (Alter & Oppenheimer, 2006). Since the sequences were not judged as likely to continue, people could be judging the sequences that they see in their present form as randomly produced and not non-randomly produced.

Third, while we controlled for the alternation rate in the sequences, it may have been too high, thus causing a gambler's fallacy response. The alternation rate for the sequences was either .45 or .55. Ayton and Fisher (2004) showed that for sequences with alternation rates of .4 or .5, about 40% of people still think that those sequences were produced by a coin toss rather than a series of basketball shots. It has also been shown that if sequences have a high enough alternation rate, people do not pay attention to the cause of the sequences (Boynton, 2003). Therefore, the alternation rate might need to be lowered to really suggest that the player is hot and causing the streak.

The fourth explanation is that people don't believe in the hot hand anymore. It has been almost 30 years since Gilovich et al.'s original study was published so there could have been a shift in society's thinking since then. It could be true that people in society have gotten smarter and are more aware of the hot hand belief now than before. This explanation, however, seems unlikely since others more recently have found the hot hand belief in other domains outside basketball (Croson & Sundali, 2005).

Fifth, the sample used in the present study differed greatly from the sample used in Gilovich et al.'s original study. In the current study, only 10 of the 151 participants (6.6%) played basketball either quite often or very often and 30% of the participants said they watched zero basketball games per year. This is quite different from Gilovich et al.'s original sample because they actively recruited basketball fans that all played at least occasionally and half were captains of intramural basketball teams (1985). Since their sample was very familiar with basketball, they might be more prone to believe in the hot hand since they are around and familiar with the stimulus that produces it. The hot hand belief is usually only found when making judgments about specific types of events, so if people are not familiar with these events and their outcomes, they could be less prone to believe in the hot hand. If this is indeed the case and only those familiar with basketball show belief in the hot hand, then this would mean that the hot hand belief is not generalizable to the whole population.

There is one possible explanation for the idea that only those familiar with basketball would believe in the hot hand. People who are not familiar with basketball or other sports may not be familiar with judging the future outcomes of trials in a sequence of events. In basketball, every time someone shoots, we make an internal judgment while the ball is in the air on whether or not that shot is going to go in. This is beneficial to do when playing or watching so that one can position themself for a rebound or form their perception on how their team is doing in the game. Therefore, those who do not have that experience judging basketball shots might not believe in the hot hand. If this is indeed the case, then this would be one instance where having expertise in a field actually impairs judgment.

Despite limitations of being able to produce the hot hand belief in a lab environment, there is still promise for future studies to be able to find the hot hand and debias it. The first and foremost variation to try is to use a sample more in line with what Gilovich et al. (1985) used in their studies. This would entail recruiting basketball players from a campus recreation center or season ticket holders for a basketball team. This would ensure that these people are very familiar with basketball and would be more likely to believe in the hot hand. The second manipulation that can be made is to represent the sequences in a different format. The present study used X's and O's because sequences are usually represented using capital letters (Lopes & Oden, 1987; Diener & Thompson, 1985), and because people use the most recent events in a sequence to influence their judgments (Oskarsson, Van Boven, McClelland, & Hastie, 2009). Depicting makes and misses in a form more like one would experience in real life, such as a video of a player shooting, might evoke belief in the hot hand. The final possible manipulation that could be made for further research is to show two sequences as being competitive by saying they are the shot records of players who are guarding each other in a game. Competition is judged as more non-random than non-competition and sequences perceived as non-random are more likely to be judged with a hot hand frame of mind (Burns & Corpus, 2004).

The hot hand is a bias in judgment that has been shown to appear in basketball (Gilovich et. al., 1985) and other domains (Croson & Sundali, 2005). The results of the current study show that it may not be generalizable to the general public, at least where basketball is concerned. Thus, more work is needed to examine the specific nature of the hot hand belief and its consequences in society.

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Tables and Figures

Figure 1

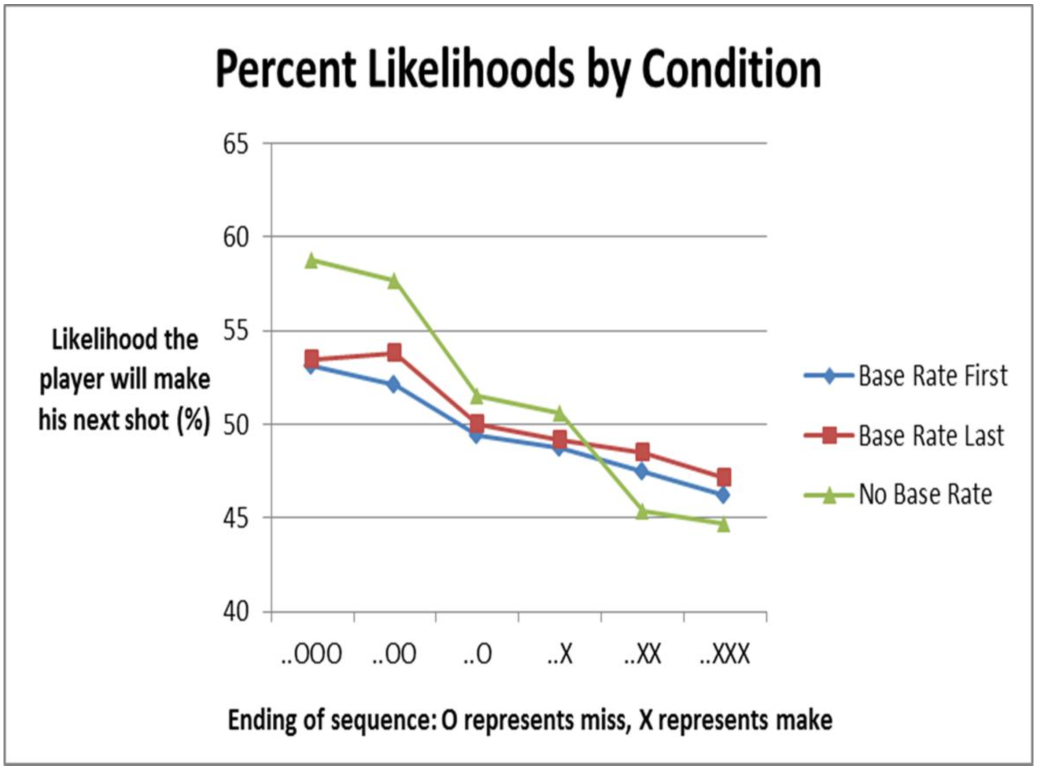

Table 1

Effects of makes, alternation rate, and end behavior of sequences on participants' judgments

Parameter	Estimate	Standard Error	95% Confidence Interval		Z
Intercept	36.2591*	5.7828	24.9251	47.5931	6.27
Sequence Makes	.3098*	0.0736	0.1656	0.4540	4.21
Sequence Alternation Rate	-0.0238	0.0825	-0.1855	0.1379	-0.29
Sequence End	-1.5233*	0.3112	-2.1332	-0.9135	-4.90

*p<.0001

Table 2

Effects of base rates on participants' judgments

Parameter	Estimate	Standard Error	95% Confidence Interval		Z
Intercept	5.4404	7.7672	-9.7831	20.6638	0.70
Sequence Makes	0.0100	0.0811	-0.1489	0.1688	0.12
Sequence Alternation Rate	0.0498	0.0891	-0.1248	0.2243	0.56
Sequence End	-1.1534*	0.3220	-1.7845	-0.5224	-3.58
Base Rate	0.8364*	0.0932	0.6537	1.0190	8.98

* p < .001

Figure 2

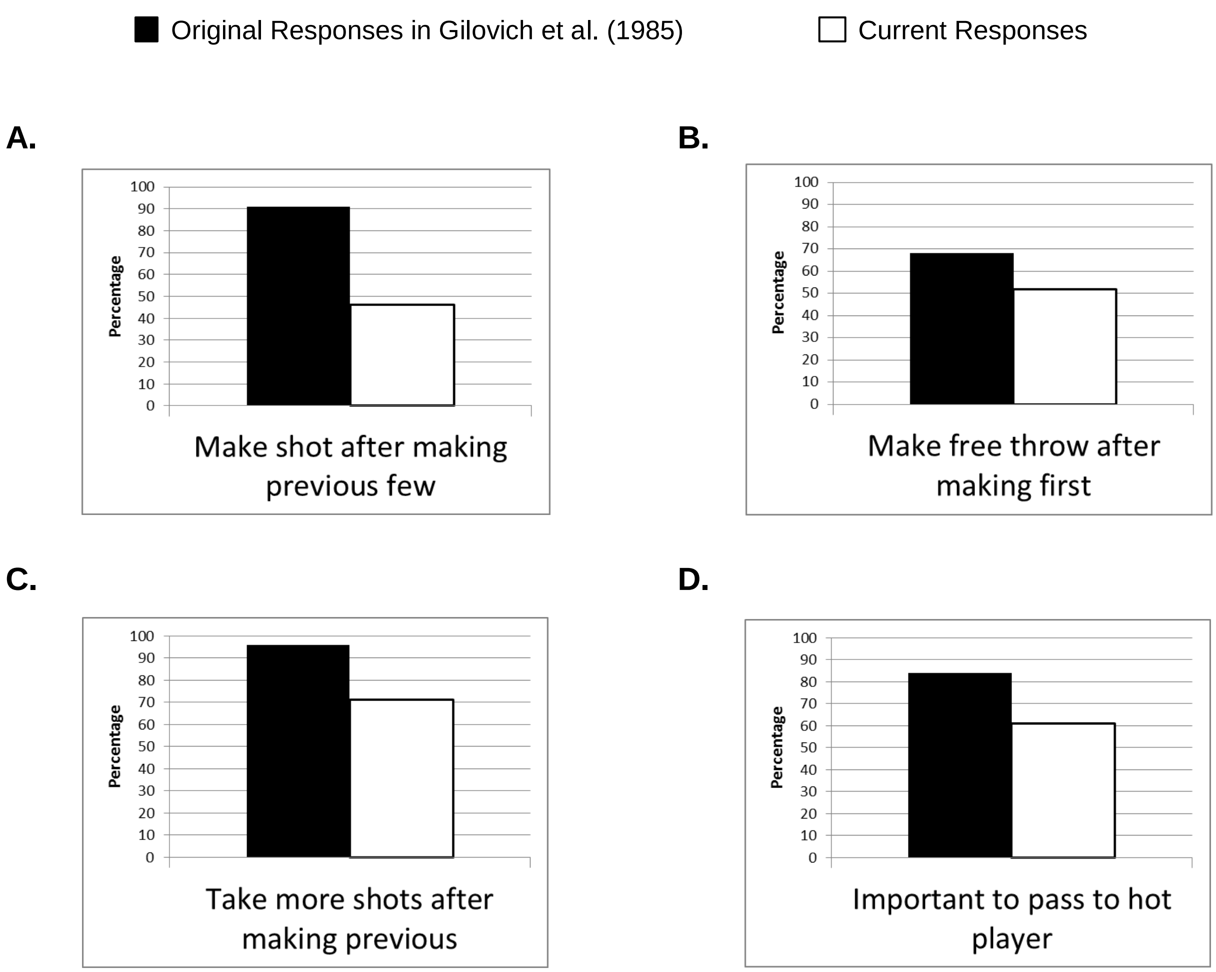

Table 3

Effects of sequence end behavior on participants by condition

Parameter	Estimate	Standard Error	95% Confidence Interval		Z
Intercept	37.2777*	5.7873	25.9349	48.6206	6.44
Sequence Makes	0.3098*	0.0736	0.1656	0.4540	4.21
Sequence Alternation Rate	-0.0238	0.0825	-0.1855	0.1379	-0.29
Sequence End	-2.4254*	0.6664	-3.7315	-1.1193	-3.64
Base Rate	0.8364*	0.0932	0.6537	1.0190	8.98
Base Rate Conditions Combined	-1.5080	1.0363	-3.5391	0.5231	-1.46
Sequence End x Base Rate Conditions	1.3354^	0.7404	-0.1156	2.7865	1.80

* $p < .001$ ^$p=.07$